Space Project Mission Operations Control Architecture (SuperMOCA)

SuperMOCA SYSTEM CONCEPT

Ancillary Document 2

Operations Center to Ground Terminal Scenarios

September 1996

ORIENTATION

The goal of the **S**pace **Pr**oject **M**ission **O**perations **C**ontrol **A**rchitecture ("SuperMOCA") is to create a set of implementation-independent open specifications for the standardized monitor and control of space mission systems. Monitoring is the observation of the performance of the activities of these systems. Controlling is the direction of the activities performed by these systems. Overall, monitor and control is the function that orchestrates the activities of the components of each of the systems so as to make the mission work. Space mission systems include:

spacecraft and launch vehicles that are in flight, and;
their supporting ground infrastructure, including launch pad facilities and ground terminals used for tracking and data acquisition.

The SuperMOCA system concept documents consist of the following:

SuperMOCA System Concept, Volume 1: Rationale and Overview
SuperMOCA System Concept, Volume 2: Architecture
SuperMOCA System Concept, Volume 3: Operations Concepts
SuperMOCA System Concept, Annex 1: Control Interface Specification
SuperMOCA System Concept, Annex 2: Space Messaging Service (SMS) Service Specification
SuperMOCA System Concept, Annex 3: Communications Architecture
SuperMOCA System Concept, Ancillary Document 1: Ground Terminal Reference Model
SuperMOCA System Concept, Ancillary Document 2: Operations Center to Ground Terminal Scenarios
SuperMOCA System Concept, Ancillary Document 3: Operations Center to Ground Terminal – Comparison of Open Protocols

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1. INTRODUCTION

1.1. INTRODUCTION

This document was developed as part of the SuperMOCA program to accomplish "The development of scenario(s) based on the architecture of the use of the ground terminal to track a spacecraft (including command transmission, telemetry reception, radio metric data acquisition)."

"Operational scenarios will be developed encompassing normal Ground Terminal operations. The scenarios will be based on the architecture developed in the first subtask, and will include Ground Terminal scheduling, command transmissions, telemetry reception, radiometric data gathering, the Ground Terminal/Control Center communications, and post-contact operations close-out."

This document is based on the SuperMOCA System Concept, Ancillary Document 1, Ground Terminal Reference Model, and includes:

- Ground Terminal Scheduling
- Command Transmissions
- Telemetry Reception
- Radiometric Data Gathering
- Ground Terminal/Control Center Communications
- Post-Contact Operations Close-Out.

1.2. CONTEXT OF TASK

A great deal of relevant work has already been accomplished within the Space Mission Operations Control Architecture (SuperMOCA) context and within the Consultative Committee for Space Data Systems (CCSDS). Figure 1-1 shows a high level view of some of this work. As shown, this Task will focus on the Management channel for the Spacecraft User, and both the Management and Transport channels for the Ground Terminal User.

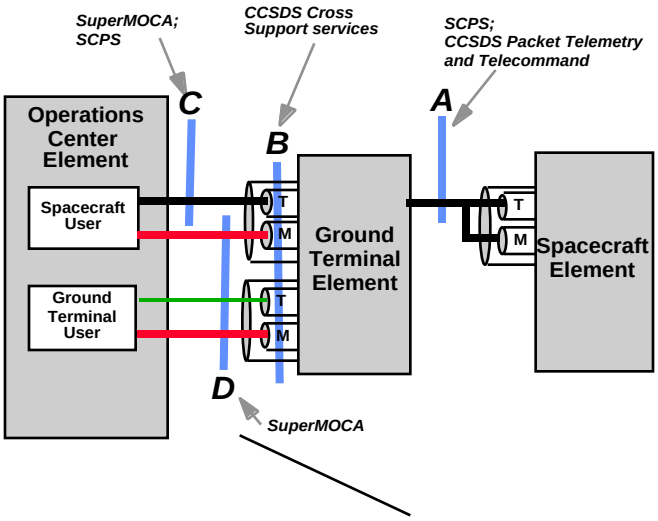

Figure 1-1 - Task Context

2. SCENARIOS MODEL

2.1. SCENARIOS PHASES

The scenarios are based on the SuperMOCA 'Plan, Use, Maintain' concept. The concept is broadly applicable across the lifecycle of a mission. It is a repetitive cycle of activities in which planning for an activity is followed by the use of internal and/or external resources to accomplish the activity, and is concluded by feedback from the activity to maintain the accuracy of relevant models, databases, etc.

Scenarios Model

As shown in Figure 2-1, the high level Scenarios Model has six parts:

Planning

Scheduling

Initiation

Operation

Termination, and

Evaluation.

Planning and Scheduling constitute the Plan phase.

Initiation, Operation, and Termination constitute the Use phase.

Evaluation constitutes the Maintain phase.

The Scenarios address the Plan and Maintain phases only superficially, concentrating on the Use phase.

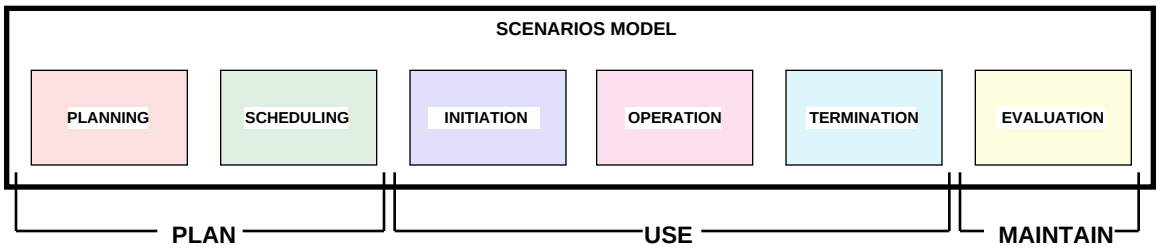

Figure 2-1 - High Level Scenarios Model

The detailed Scenarios Model shows each of the six subphases and the processes and data used in each, as illustrated in Figure 2-2 through Figure 2-7.

2.1.1. PLAN

The Plan phase has two components. First is the Planning process and second is the Scheduling process.

Planning is an activity which actually takes place externally to the Ground Terminal Reference Model. However, it involves the (logical) Ground Terminal in that the planning process requires access to descriptions of Ground Terminal capabilities and equipment lists. The planning process utilizes the information in evaluating the suitability and desirability of the specific Ground Terminal for the mission need. The Station Capabilities File and the Station Equipment List may be kept at a centralized facility along with those of other Ground Terminals belonging to the provider organization, but they are logically a part of the Ground Terminal.

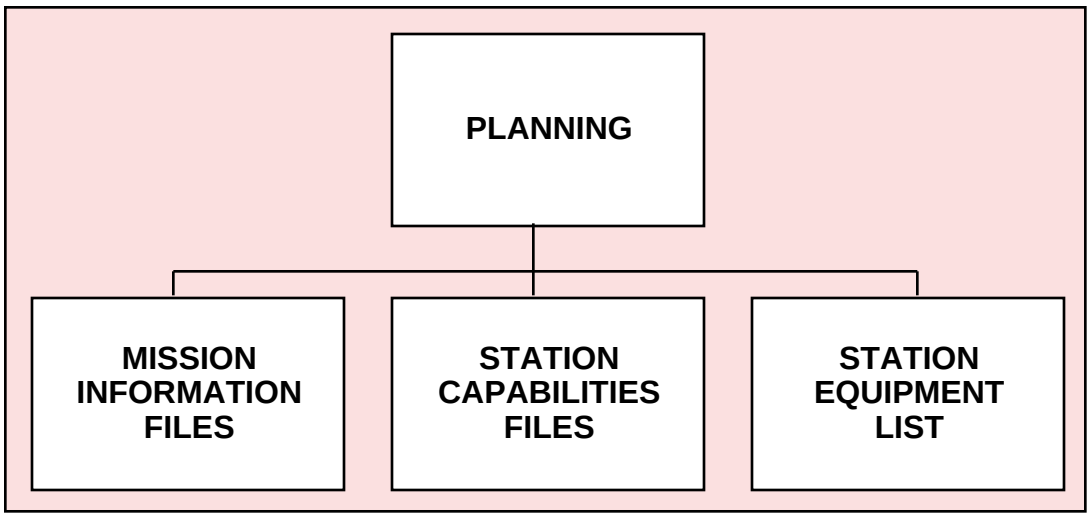

Figure 2-2 - Planning

The Scheduling process is initiated by a time slot request from the using organization, accompanied by a "Required Equipment List (or a Required Capabilities List). The (logical) Ground Terminal examines the request and determines the Ground Terminal equipment availability for the requested time period. The (logical) Ground Terminal then responds to the user with either an accept message and integrates the request into its schedule, or a reject message, optionally with a list of alternative available time slots.

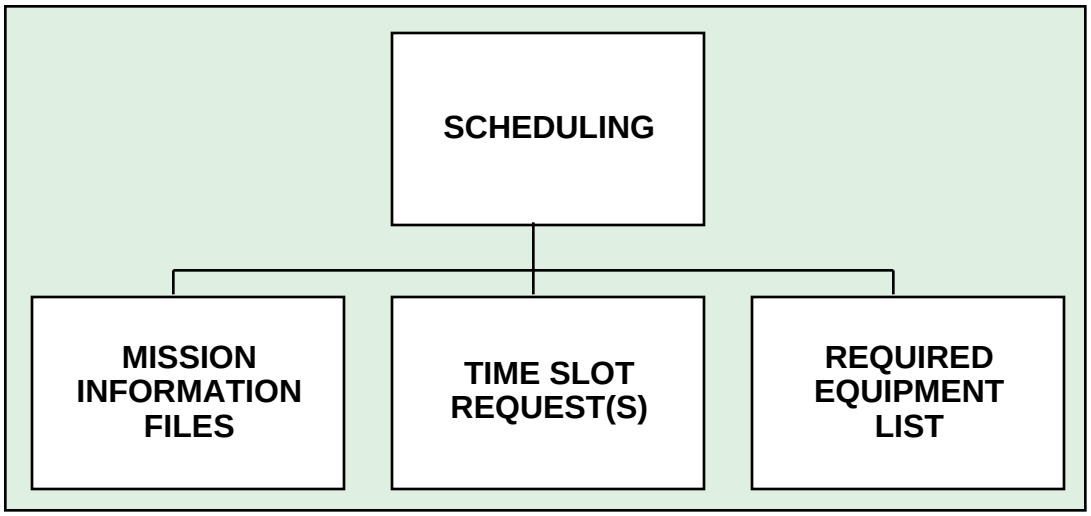

Figure 2-3 - Scheduling

2.1.2. USE

The Use phase is made up of three parts or subphases; Initiation, Operation, and Termination.

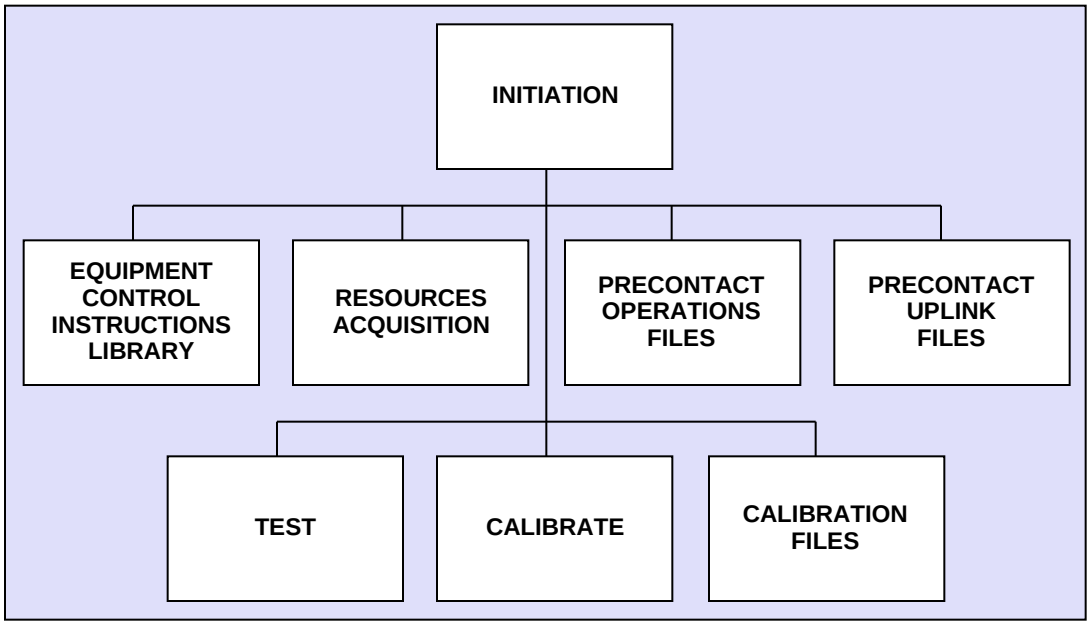

Figure 2-4 - Initiation

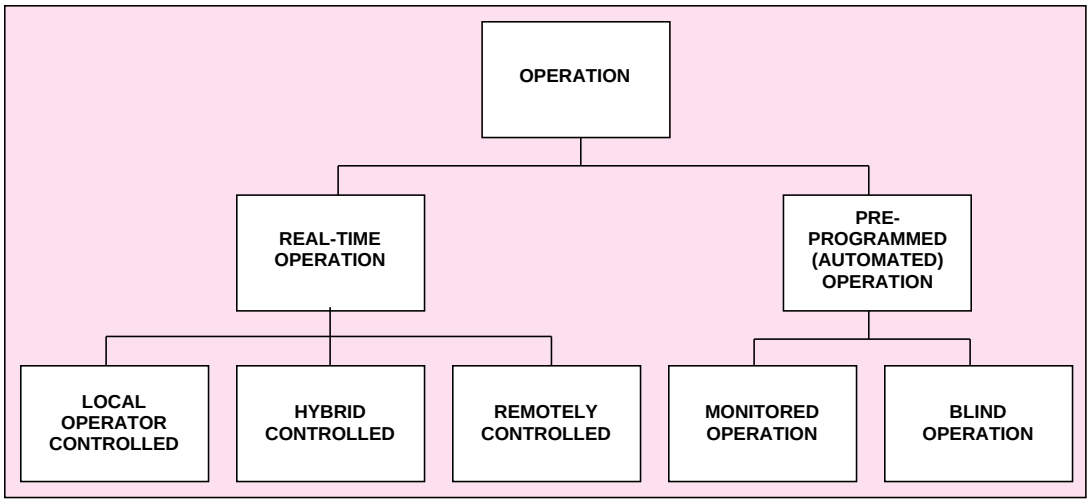

Figure 2-5 - Operation

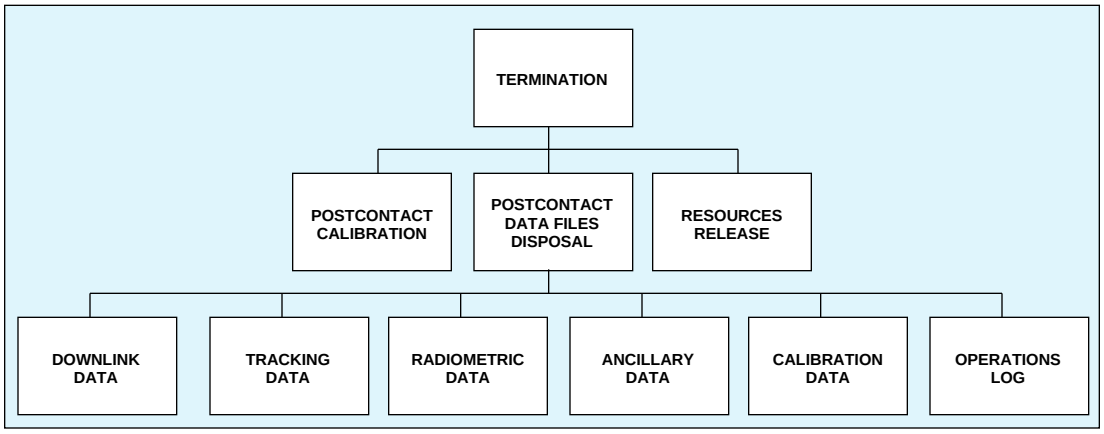

Figure 2-6 - Termination

The execution of the Use phase varies widely, depending upon the nature of the contact, for example tracking only, data acquisition only, tracking and real-time spacecraft monitoring and commanding, etc., and the type of Ground Terminal.

2.1.3. MAINTAIN

The Evaluation activity constitutes the Maintenance phase. Evaluation includes the gathering of post-contact reports from the user and from the Ground Terminal itself. The reports are analyzed by the Ground Terminal (or its Network Control Center) for information which needs to be fed back into the Station Capabilities File and the Station Equipment List. Resulting changes to those data files conclude the Maintenance activity.

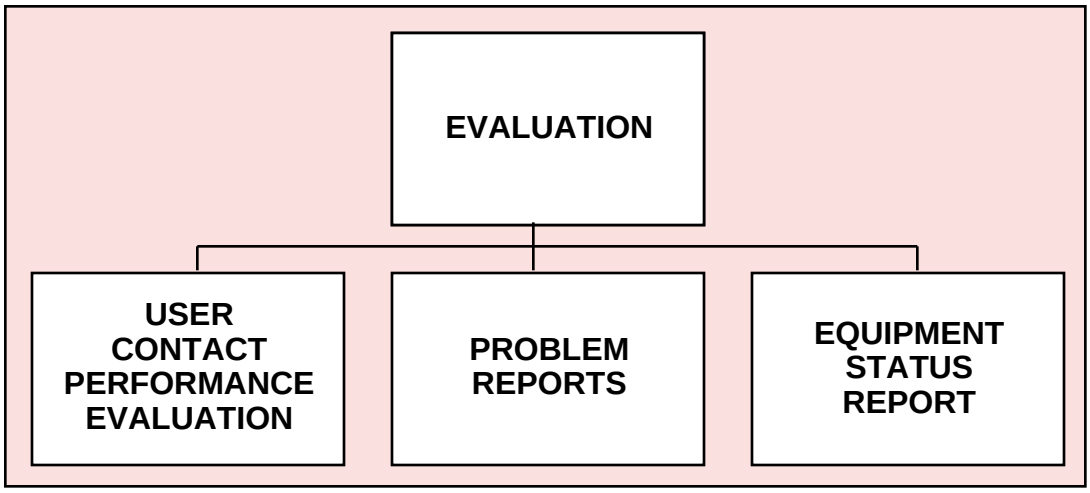

Figure 2-7 – Evaluation

3. SCENARIOS ENVIRONMENT

3.1. SCENARIO GROUND TERMINAL TYPES

There are several "flavors" of operations, determined by the Ground Terminal implementation.

- Locally Operated - A Ground Terminal may have no remote control capabilities, being entirely configured and operated by local operators. Locally Operated Ground Terminals are not a subject for this Task and are not included in these scenarios.

- Hybrid - A Ground Terminal may have remote control capability at the equipment level, but require inter-equipment configuration by local operators.

- Fully Remotely Operated - A Ground Terminal may be fully remotely controllable, including inter-equipment configuration.

- Autonomous - A Ground Terminal may be autonomous as opposed to remotely controlled, in which case it executes a script of activities at a specified time or upon a specified event. Depending upon the Ground Terminal capabilities, the script may range from a relatively simple series of time triggered actions to a complex series of activities conditioned upon events in the Ground Terminal and/or in the spacecraft. An Autonomous contact may or may not include real-time monitoring of data and/or events by the User Operations Center.

3.2. SCENARIO TYPES

The focus of the scenarios in this document is on operations in which one organization (the User, e.g. NASA) uses the Ground Terminal resources of another agency (the Provider, e.g. DoD) to communicate with and operate the first agencies (NASA's) spacecraft.

An important variation of the basic scenario is when the User also uses the Ground Terminal resources of a third organization (a second Provider, e.g. a commercially owned and operated Ground Terminal) to extend the User Operations Center operation with the spacecraft in an uninterrupted, continuous (seamless) manner. That is, there is a handover of spacecraft contact and service support from one Ground Terminal Provider to another Ground Terminal Provider from a different agency in a manner which is (nearly) invisible to the Users Spacecraft Operators (although it may be highly visible to the Users *Ground Terminal* operators).

3.3. SERVICE SYSTEM OPTIONS

At a minimum, a contact activity involves at least one subsystem from one of the five service systems shown in Figure 3-1, taken from the Ground Terminal Reference Model part of this Task. At a theoretical maximum it could involve every subsystem of every service system (some of the service systems, e.g. Tracking Service and Correlative Service, may involve more than one subsystem each). (In order to limit the size of this scenario description, it will be based on a contact which uses a single Space Link subsystem, a single Space Data subsystem, and a single Radiometric subsystem.) The Initiation, Operation, Termination sequence is followed for each of the subsystems

Figure 3-1 - Reference Model Service Systems

4. SCENARIOS

4.1. SCENARIOS BASELINE

The following provide the baseline used in generating the scenarios:

- Ground Terminals are of the "Fully Remotely Operated" flavor
- Ground Terminal Equipments have local Virtual Interface (e.g. Virtual Mission Device) implementations
- Contact uses one Space Link Subsystem, one Space Data Subsystem, and one Radiometric Subsystem
- Contact includes real-time Ground Terminal relay of one CCSDS Packet ID and one CCSDS Virtual Channel to Operations Center
- All downlink data is stored on-site at Ground Terminal
- Real-time commanding and data monitoring is performed by Operations Center

4.2. ASSUMPTIONS

The following assumptions were made in order to generate the scenarios:

- Plan Phase utilizes standard commercial open network and protocols with access control and encryption
- Use Phase utilizes standard commercial open network and protocols with access control and encryption for Ground Terminal operation and monitoring
- Use Phase utilizes closed network, open protocols, access control, and encryption for "mainstream" data, i.e. data from spacecraft and commands to spacecraft
- Maintain Phase utilizes standard commercial open network and protocols with access control and encryption for post-contact reports and data base updates
- Plan and Maintain Phases are sufficiently general that, for the purposes of these scenarios, and they do not need to be tailored to the specific scenario
- Scheduling constraints allow single initiation process and single termination process
- Spacecraft transmitter (transponder) has separate Tracking, Data, and Beacon Modes
- Beacon Mode is used for radiometry

4.3. SCENARIO 1 - INTER-AGENCY OPERATION

User (Client) Organization “A” Using Ground Terminal (Server) of Organization “B”

4.3.1. PLAN PHASE

All the Planning and Scheduling activities use commercial, standard open networks and protocols (e.g. Internet), with access restrictions and commercial encryption.

Table 4-1 - Plan

	PLANNING
1	The User (Agency ‘A’ Operations Center) determines the need for Ground Terminal support which can not be satisfied by its normally used agency network.
2	The User selects a candidate external (Agency ‘B’) Ground Terminal Network which may be able to satisfy its requirement.
3	The User accesses the (logical) Ground Terminal(s) Station Capabilities Files (which may be physically located at an Agency ‘B’ Ground Terminal Network Control Center).
4	The User evaluates the capabilities of the station(s) to meets its requirement.
5a	If the capabilities are not sufficient, an alternative candidate is selected and the process begins again at Step 2, OR
5b	If the capabilities are sufficient, the User determines the Ground Terminal equipment required from the Ground Terminal Equipment List. (OR the User prepares a Required Capabilities List based on the Station Capabilities File, and equipment selection is determined by the Ground Terminal or its Network Control Center during the Scheduling process).
	SCHEDULING
6	The User (Agency ‘A’ Operations Center) transmits an Operations Schedule Request to the (Agency ‘B’) Ground Terminal (or its Network Control Center). The Request includes the desired time slot(s) and the required Equipment list (or Required Capabilities List).
7a	The Ground Terminal (or its Network Control Center) evaluates the request through its scheduling process and returns an Accept message to the User and places the operation on its schedule, OR
7b	The Ground Terminal (or its Network Control Center) returns a Reject message to the User. Optionally, the Ground Terminal (or its Network Control Center) may attach a list of open time slots or suggested alternative times to the Reject message, to assist the User.

4.3.2. USE PHASE

The Use Phase may be performed with processes and equipment control being executed by timeline, or event or both. Control functions may take place at any level from voice instructions to a Ground Terminal operator to high level goal-oriented instructions to a Ground Terminal operations executive AI entity.

Remote monitoring of Ground Terminal equipment (and the spacecraft as well) may or may not take place. For example, the operation may be a totally automatic, pre-programmed, autonomous station operation with no Ground Terminal communications with the outside world at all.

4.3.2.1.Initiation

At some time (specific to the Ground Terminal) before the scheduled spacecraft acquisition, the Initiation process of the Use Phase takes place. The Initiation process is started by either the User or the Ground Terminal, depending upon the provider organizations standard practices.

First, communications are established and verified. These communications may be voice only, data only, or data and voice, depending on the type of Ground Terminal operation to take place.

For a fully featured contact, Precontact Operations Files are transferred from the user Operations Center to the Ground Terminal. These files usually include an operations script (for either human or AI operators) specifying the expected activities versus time or event, predicted antenna pointing angles versus time, and disposition instructions for any data files to be gathered by the Ground Terminal during the operation. Any files which are to be uplinked to the spacecraft directly by the Ground Terminal are transferred to the Ground Terminal. For remotely controlled operations, the required files of Equipment Control Instructions are uploaded from the Ground Terminal to the Operations Center. The level of these instructions may vary from equipment unique binary patterns to very high level script or goal type instructions for a highly intelligent Autonomous Ground Terminal.

After these data transfers the scheduled Ground Terminal resources are acquired and tests are conducted (either by local operators or remotely by the Operations Center) to verify their acquisition and correct configuration. This verification is followed by any required calibration/calibration measurement operations and the gathering of requested calibration data files. Upon successful conclusion of these steps the Ground Terminal is ready for the contact operation.

If there is not great pressure for other use of the involved subsystems, all the Initiation processes may be executed pre-contact. Alternatively, Initiation may take place at different times for the different subsystems used in a single contact. For example, a given contact with a spacecraft might involve first a tracking operation followed by spacecraft data acquisition and commanding, followed by acquisition of radiometric data

with the spacecraft transmitter in a “beacon only” mode. The Initiation process for the tracking operation would begin prior to spacecraft acquisition, that for the space data operations could take place during the tracking operation, and the process for the radiometric operations could take place during the space data operations.

4.3.2.2.Operation

Each required system/subsystem is configured for operation. After acquisition of the spacecraft (or other item for correlative data), the operation is continued with equipment control being executed by timeline, or event or both. As noted previously, the control function may take place at any level from voice instructions to a Ground Terminal operator to high level goal-oriented instructions to a Ground Terminal operations executive AI entity.

Also as noted, remote monitoring of Ground Terminal/equipment (and the spacecraft as well) may or may not take place. For example, the operation may be a totally automatic, pre-programmed, station operation with no Ground Terminal communications with the outside world at all.

In this scenario the Ground Terminal is of the Fully Remotely Operated flavor, and the Ground Terminal equipments have virtual interfaces which mask the device specific aspects behind a standardized interface for that type of device (e.g. a receiver), similar to the Virtual Mission Device (VMD) concept used in the MMS and SP-50 protocols. Also, the contact involves the use of a Space Link Subsystem, a Space Data Subsystem, and a Radiometric Subsystem (see the Ground Terminal Reference Model for details of these).

In this scenario, the Operations Center (User) is assumed to have a Spacecraft Operator (SO) and a Ground Systems Operator (GSO). Each of these may be one or more humans, or one or more machines, or some mix of humans and machines. The actions of the SO are noted ONLY when they affect the Ground Terminal operation.

In addition, throughout the following operations real-time commanding and spacecraft data transfer activities may be taking place. Communications between the Operations Center and the Ground Terminal staff may be taking place via both voice and interactive electronic messaging. As long as these activities do not affect the operation of the Ground Terminal equipments they are not noted.

4.3.2.3.Termination

Termination involves first any required post-contact calibration operations, second, the transfer of any accumulated data files from the Ground Terminal to the Operations Center (or other designated destination), and third, the release of the Ground Terminal resources acquired for the contact operation.

The Resources Release process is often in two steps - all Ground Terminal resources except data storage used for the accumulated data are released immediately, and

data transfer of the accumulated data and release of the data storage resources take place at a later post-contact time.

All the Termination processes may be executed post-contact, or, as in Initiation, Termination may take place at different times for the different subsystems used in a single contact. For example, a given contact with a spacecraft might involve first a tracking operation followed by spacecraft data acquisition and commanding, followed by acquisition of radiometric data with the spacecraft transmitter in a "beacon only" mode. The Termination process for the tracking operation could occur during the space data operations, that for the space data operations could take place during the radiometric operation, and the process for the radiometric operations could take place at the end of the contact.

Table 4-2 - Use

	INITIATION
1	Ground Systems Operator (GSO) - Establish and verify Operations Center/Ground Terminal voice and data communications
2	GSO - Transfer operations script to Ground Terminal
3	GSO - Transfer predicted antenna pointing angles versus time file to Ground Terminal
4	GSO - Transfer disposition instructions for pre- and post-contact Space Link and Radiometric calibration files to Ground Terminal
5	GSO - Transfer disposition instructions for spacecraft downlink data files to be accumulated at Ground Terminal to Ground Terminal
6	GSO - Transfer uplink files which are to be uplinked to the spacecraft by the Ground Terminal
7	GSO - Transfer the required files of Equipment Control Instructions from the Ground Terminal to the Operations Center. (In this scenario, these files describe the virtual interface to each of the Ground Terminal equipments to be used, and are linked to the Operation Center control software. This allows the GSO to use his/her/its standard GUI or other interface to control the Ground Terminal equipments. Other possible scenarios include those in which the Ground Terminal has "intelligent" subsystems wherein the Operations Center control is exercised at the subsystem level and might include "rules" and "goals, rather than "control commands".)
8	GSO - Configure Space Link and Radiometric subsystems for pre-contact calibrations
9	GSO - Execute Space Link calibration sequence and verify that pre-contact calibration data has gone to Ground Terminal file
10	GSO - Execute Radiometric calibration sequence and verify that pre-contact calibration data has gone to Ground Terminal file

11 GSO - Configure for contact, including antenna slew to spacecraft acquisition angles and antenna in Programmed mode, and all Space Data System protocol parameter settings, including uplink/downlink retransmission variables

12 GSO - Transfer from Initiation to Operation subphase

OPERATION

13 GSO - Upon spacecraft signal acquisition, monitor signal strength to triggering point for data operations

14 GSO - Switch antenna to Auto-track mode

15 Spacecraft Operator (SO) - Command downlink data on

16 GSO - Monitor Space Link and Space Data Uplink and Downlink subsystems for synchronization lock at frame, R-S Decoder, Virtual Channel, and Packet levels.

17 SO - Configure spacecraft data system and verify (including command system)

18 GSO - Continue monitoring performance of Space Link and Space Data subsystems, making adjustments in real-time to (virtual) Ground Terminal equipments as required

19 GSO - Per the Contact Script and the SO, transmit to the spacecraft the uplink files stored at Ground Terminal

20 GSO - Per the Contact Script and the SO, monitor the Ground Terminal acquisition and storage of the required downlink data

21 GSO - Per the Contact Script and the SO, at the end of the spacecraft data acquisition, commanding and real-time operations period configure Ground Terminal for scheduled Radiometric measurements and notify SO

22 SO - Configure the spacecraft for radiometric measurement; switch spacecraft transmitter to beacon mode

23 GSO - Per the Contact Script and the SO, monitor the Ground Terminal acquisition and storage of the required radiometric data

24 GSO - Per the Contact Script and the SO, at the end of the radiometric data acquisition period, configure Ground Terminal for scheduled end of contact

25 SO - Configure the spacecraft to no-contact mode

26 GSO - Per the Contact Script and the SO, at the end of the contact period, configure Ground Terminal for scheduled end of contact

27 GSO - Transfer from Operations to Termination subphase

TERMINATION

28 GSO - Configure Space Link and Radiometric subsystems for post-contact calibrations

29 GSO - Execute Space Link calibration sequence and verify that post-contact calibration data has gone to Ground Terminal file

30 GSO - Execute Radiometric calibration sequence and verify that post-contact calibration data has gone to Ground Terminal file

31 GSO - Verify post-contact data operations schedule for transfer of Ground Terminal stored data files to user(s)

32 GSO - Release all non-data storage Ground Terminal resources

33 GSO - At scheduled post-contact data operations time, establish (or verify) data communications connectivity between Ground Terminal and destination(s) of data

34 GSO - Verify successful transfer of Ground Terminal stored data to destination(s)

35 GSO - Release Ground Terminal data storage resources

36 GSO - Close ground operations part of contact history

4.3.3. MAINTAIN PHASE

The Evaluation activity constitutes the Maintain Phase. Evaluation includes the gathering of post-contact reports from the user and from the Ground Terminal itself. The reports are analyzed for information which needs to be fed back into the Station Capabilities File and the Station Equipment List. Resulting changes to those data files conclude the Maintenance activity.

Table 4-3 - Maintain

EVALUATE

1 The User transmits a post-contact report to the Ground Terminal.

2 The Ground Terminal generates problem reports related to the contact.

3 The Ground Terminal generates a post-contact equipment status report.

4 The Ground Terminal (or its Network Control Center) evaluates the above reports, determining what, if any, inputs need to be made to the Ground Terminal Capabilities File, the Ground Terminal Equipment List, and the Ground Terminal Status File.

5 The Ground Terminal (or its Network Control Center) makes the required changes to the relevant databases.

4.4. SCENARIO 2 - SEAMLESS HANDOFF

The Scenario Baseline is the same as for Scenario 1, with the addition of the Seamless Handover operation.

4.4.1. SCENARIOS BASELINE

The baseline for the first Ground Terminal is same as in Scenario 1 plus the following:

- The second Ground terminal belongs to a different agency from either the Operations Center or the first Ground Terminal

- A “first Ground Terminal to Operations Center to second Ground Terminal” route is used for handover synchronization to avoid the need for direct, inter-agency Ground Terminal to Ground Terminal data connections

- Both Ground Terminals are of the “fully remotely operated” flavor

- The equipments in both Ground Terminals have local virtual interface (e.g. Virtual Mission Device) implementations

- The second contact uses one Space Link subsystem and one Space Data subsystem only (i.e. there is no Radiometry at the second Ground Terminal)

- The second contact includes real-time Ground Terminal relay of one CCSDS Packet Id and one CCSDS Virtual Channel to the Operations Center

- All second contact downlink data is stored on-site at Ground Terminal

- Real-time commanding and data monitoring are performed by the Operations Center through both Ground Terminals

4.4.2. ASSUMPTIONS

The Assumptions are the same as for Scenario 1, plus:

- The Plan Phase and the Maintain Phase for the second Ground Terminal are functionally identical with Scenario 1 at this level.

- Within the Use Phase, the Initiation Subphase and the Termination Subphase for the second Ground Terminal are identical with Scenario 1.

4.4.3. USE PHASE SCENARIO

The execution of the Use phase in this Scenario is the same for each of the two Ground Terminals except for the Seamless Handover operation. Therefore this Scenario addresses only that process.

The three subphases of the Use phase are Initiation, Operation, and Termination. Each is addressed separately.

4.4.3.1.Initiation

The Initiation Subphase for both Ground Terminals the same as that for the first Ground Terminal, as described in Scenario 1, except that in the Operations Script and the information files transferred from the Operations Center, the handover process description and settings are included.

4.4.3.2.Operation

Each required system/subsystem is configured for operation. After acquisition of the spacecraft (or other item for correlative data), the operation is continued with equipment control being executed by timeline, or event or both. As in Scenario 1, the control function may take place at any level from voice instructions to a Ground Terminal operator to high level goal-oriented instructions to a Ground Terminal operations executive AI entity, and the remote monitoring of Ground Terminal/equipment (and the spacecraft as well) may or may not take place. For example, the operation may be a totally automatic, pre-programmed, station operation with no Ground Terminal communications with the outside world at all.

Operations Center to Ground Terminal 1 Operation is the same as described in Scenario 1 up to the end of Radiometric data gathering. At that point, the actions become as shown in Table 4.

During the operation with Ground Terminal 1, the Operations Center has performed the Initiation subphase (as described in Scenario 1) with Ground Terminal 2

Table 4-4 - Scenario 2, Use Phase

	Operations Center to Ground Terminal 1 Operation is the same as described in Scenario 1 up to the end of Radiometric data gathering. At that point, the actions become:
23	Ground Systems Operator (GSO) - Per the Contact Script and the SO, monitor the Ground Terminal acquisition and storage of the required radiometric data
24	GSO - Per the Contact Script and the SO, at the end of the radiometric data acquisition period, configure Ground Terminal for data acquisition and commanding
25	Spacecraft Operator (SO) - Command downlink data on
26	GSO - Monitor Space Link and Space Data Uplink and Downlink subsystems for synchronization lock at frame, R-S Decoder, Virtual Channel, and Packet levels.
27	SO - Configure spacecraft data system and verify (including command system)
28	GSO - Continue monitoring performance of Space Link and Space Data subsystems, making adjustments in real-time to (virtual) Ground Terminal equipments as required
29	During the operation with Ground Terminal 1, the Operations Center has performed the Initiation subphase (as described in Scenario 1) with Ground Terminal 2
30	GSO - Configure Ground Terminal 2 for handover operation
31	GSO - Begin Operation subphase with Ground Terminal 2

32	SO - Configure the spacecraft for Ground Terminal handover
33	GSO - Per the Contact Script and the SO, at the scheduled handover time, configure Ground Terminal 1 for handover

There are two candidate handover techniques.

In the first, Ground Terminal 2 acquires and monitors the downlink data in a synchronize mode which establishes the current values of counters, data IDs, etc., at the various levels of space/ground protocols in use. When synchronization is verified by the GSO, the GSO commands the Ground Terminal 1 transmitter off and the Ground Terminal 2 transmitter on. A very short interruption in data would take place due to the transmitter off/on process and possibly due to differences in speed-of-light delay times to the spacecraft from the two Ground Terminals. However, protocol resynchronization would take place very quickly and the two way data transmissions would immediately resume.

4.4.3.2.1.Operation (Type 1 Handover)

In the first technique, Ground Terminal 2 acquires and monitors the downlink data in a synchronize mode which establishes the current values of counters, data IDs, etc., at the various levels of space/ground protocols in use. When synchronization is verified by the GSO, the GSO commands the Ground Terminal 1 transmitter off and the Ground Terminal 2 transmitter on. A very short interruption in data would take place due to the transmitter off/on process and possibly due to differences in speed-of-light delay times to the spacecraft from the two Ground Terminals. However, protocol resynchronization would take place very quickly and the two way data transmissions would immediately resume.

Table 4-5 - Scenario 2, Type 1 Handover

Type 1 34a	GSO - Monitor both Ground Terminals for space/ground protocol synchronization
Type 1 34b	GSO - When synchronization is verified, at or after scheduled handover time, turn Ground Terminal 1 transmitter off
Type 1 34c	GSO - Turn Ground Terminal 2 transmitter on
Type 1 34d	SO - Verify continued data operations with spacecraft

4.4.3.2.2.Operation (Type 2 Handover)

In the second technique, the SO and the GSO place the space/ground protocols on both the spacecraft and Ground Terminal 1in a “Pause” mode. Space/Ground data communications stop. The GSO turns off the transmitter at the first Ground Terminal

and ends its operation with the spacecraft. The GSO obtains all the running values of the active space/ground protocols from Ground Terminal 1, and sends them to Ground Terminal 2, causing them to become the current values in the Ground Terminal 2 protocol processes. The GSO then turns on the transmitter at the second Ground Terminal and begins its operation. The SO commands the spacecraft to initiate a “Resume” process. The Ground Terminal 2 and the spacecraft have now established protocol synchronization (through this external process) and data operations resume. (This technique would cause a significantly longer data outage during the handover process and is probably not as robust as the first technique, but allows for simpler implementations.

Table 4-6 - Scenario 2, Type 2 Handover

Type 2 34a	SO - Place spacecraft data system in “Pause” mode
Type 2 34b	GSO - Place Ground Terminal 1 in “Pause” mode
Type 2 34c	GSO - Turn off Transmitter at Ground Terminal 1
Type 2 34d	GSO - Transfer space/ground protocol parameter values from Ground Terminal 1 to Ground Terminal 2
Type 2 34e	GSO - Turn on transmitter at Ground Terminal 2
Type 2 34f	SO - Place spacecraft data system in “Resume” mode
Type 2 34g	SO - Verify continued data operations with spacecraft

Whichever type of handover is used, the operation again converges at this point, where Ground Terminal 1 ends its activities and Ground Terminal 2 continues the contact.

Table 4-7 - Scenario 2, Use Phase Continued

35	GSO - Per the Contact Script and the SO, at the end of the first contact period, configure Ground Terminal 1 for scheduled end of contact
36	GSO - Transfer Ground Terminal 1 from Operations to Termination subphase
37	GSO - Continue monitoring performance of Space Link and Space Data subsystems, making adjustments in real-time to (virtual) Ground Terminal 2 equipments as required
38	GSO - Per the Contact Script and the SO, transmit to the spacecraft the uplink files stored at Ground Terminal 2
39	GSO - Per the Contact Script and the SO, monitor the Ground Terminal 2 acquisition and storage of the required downlink data
40	GSO - Per the Contact Script and the SO, at the end of the contact period, configure Ground Terminal 2 for scheduled end of contact
41	SO - Configure the spacecraft to no-contact mode

42 GSO - Transfer Ground Terminal 2 from Operations to Termination subphase

4.4.3.3.Termination

The Termination subphase is the same for both Ground Terminals, and is as described in Scenario 1.